

Root Uptake of Arsenic in Common Plants and Vegetables

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ABSTRACT

The presence of arsenic in Bangladesh, Argentina, Chile, China, India, Mexico, and United States soil samples recently drew the attention of the World Health Organization due to the toxicity these elements produce. Arsenic is a common groundwater and soil contaminant, particularly in rural areas; the mean Arsenic levels within United States soil are 5.0 mg/kg. Excessive exposure to inorganic arsenic has been linked to vomiting, abdominal pain, and diarrhea. Inorganic arsenic is also a confirmed carcinogen. The first symptoms of long-term exposure to high levels of inorganic arsenic (for example, through drinking-water and food) are usually observed in the skin, and include pigmentation changes, skin lesions, and hard patches on the palms and soles of the feet (hyperkeratosis). These occur after a minimum exposure of approximately five years and may be a precursor to skin cancer. In addition to skin cancer, long-term exposure to arsenic may also cause cancers of the bladder and lungs. These elements contaminate and harm plant life—therefore increasing unsustainability in local ecosystems. Arsenic in the soil is generally found to be a mix of As(III) and As(V).

Through Lemont High School's Exemplary Student Research Program (2018-2020), students worked closely with Dr. Olga Antipova (Argonne National Laboratory) and George Sterbinsky (Argonne National Laboratory) to examine the relationship between the contamination of these plants with heavy metals and their root uptake with a focus on arsenic. Our student group participated in testing, observation, and analysis of plant uptake of arsenic to determine the long-term impacts of element toxicity and its relation to plant vitality. It's essential to understand the allowance of these elements in ground-rooted plants to produce a high confidence level to regulate these elements in consumer products.

Conclusion

In conclusion, Arsenic occurs in two forms: Arsenic(III) and Arsenic(V). Both are toxic to animals and humans however Arsenic(III) is more toxic. This is because Arsenic(III) easily binds to proteins and thus enters cells without difficulty causing damage. Arsenic(V) does not have this ability to enter the cells through this process. Arsenic(V) needs to get reduced into Arsenic(III) in order for this to occur.

Our findings (shown graph B) reveal that arabidopsis had the highest absorption of Arsenic (V). Carrots and lettuce had the lowest absorption rate of Arsenic (V). However, carrot, lettuce, and tomato convert Arsenic(V) into the more dangerous Arsenic (III). When testing lettuce at different points, it was found that lettuce had the highest absorption point at 3mm from the tip of the root.

Upon completion of this experiment, there are two different avenues to research. The first is changing the concentration and the timeframe and the second is to test different plants that are more prevalent in the areas of the world that have high levels of arsenic soil contamination.

MOTIVATION

In recent years, there has been a surprising amount of arsenic in soil samples of many Asian and South American nations as well as the United States. Arsenic in its inorganic form is extremely toxic and can lead to sever short and long term consequences. Immediate symptoms of arsenic poisoning consist of vomiting, diarrhea, muscle cramping, and pain. Long term arsenic poisoning can be visible in the skin through lesions and pigmentation changes. Long term exposure to arsenic can also cause diabetes, pulmonary disease, and cardiovascular disease which consequently leads to heart attacks and in extreme cases death. The International Agency for Research on Cancer (IARC), US National Toxicology Program (NTP) and US Environmental Protection Agency (EPA) classify arsenic to be carcinogenic to humans, with sufficient evidence of them causing skin, liver, and prostate cancer. It is vital that we monitor our consumption of arsenic, and diminish it whenever possible.

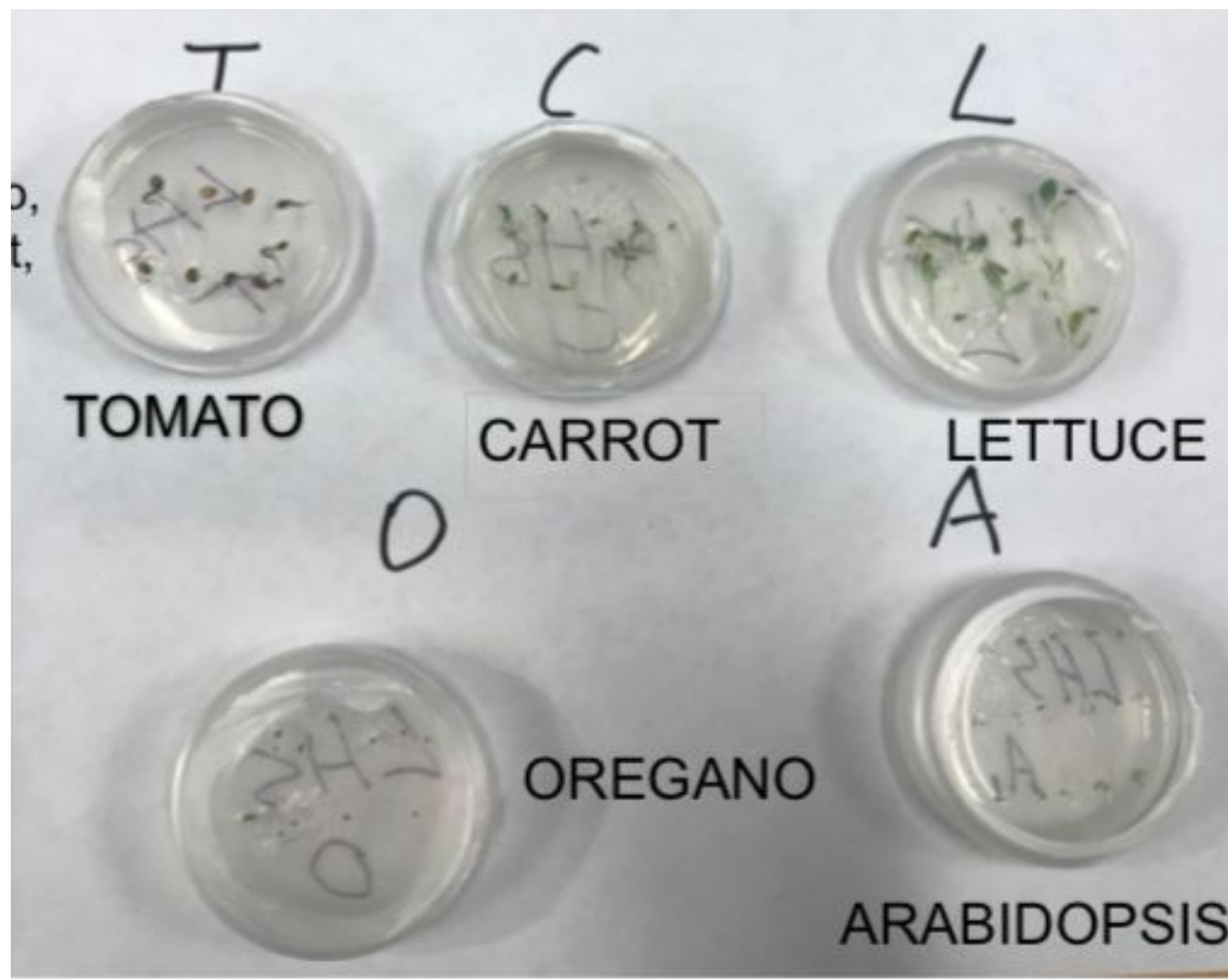
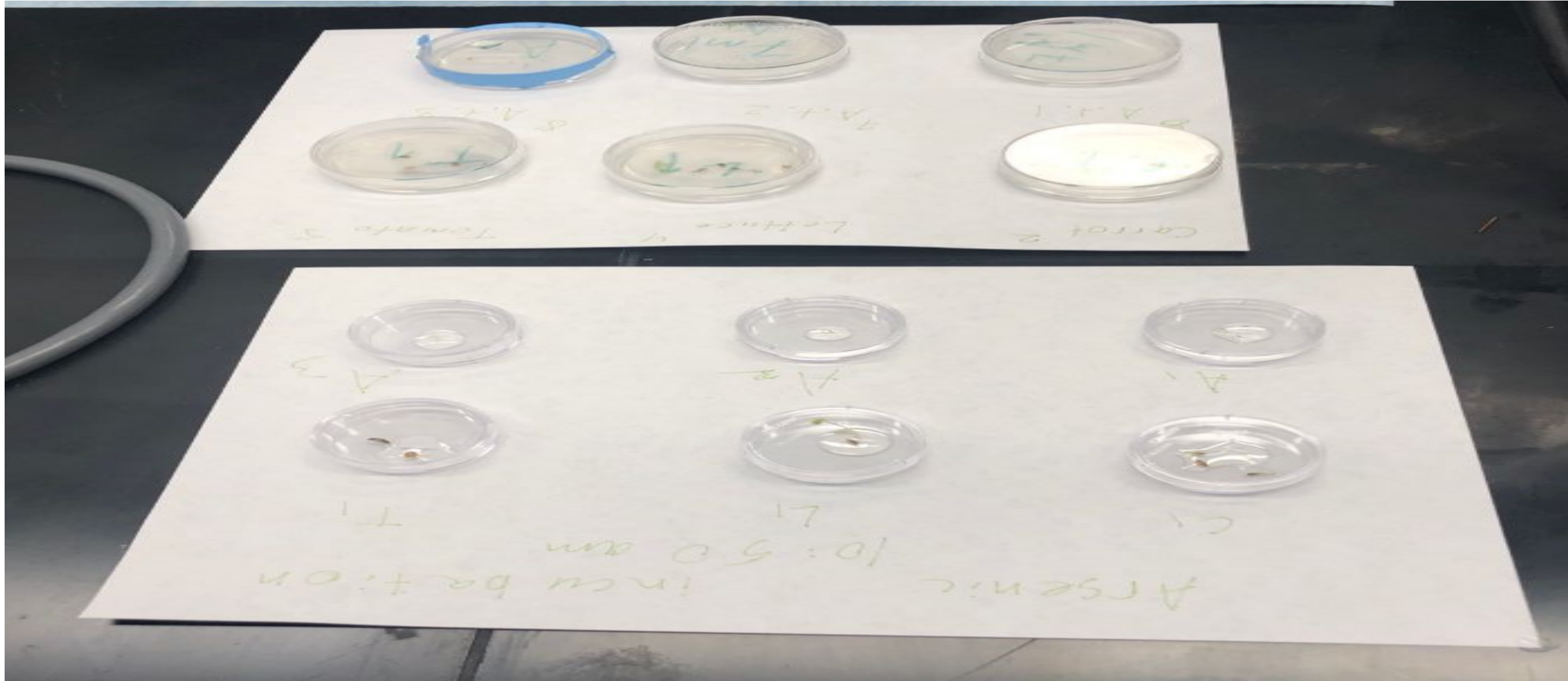
METHODS

Arabidopsis, Carrot, Lettuce, Oregano, and Tomato seeds will be planted in agarose gels. After one week the plants were harvested, mounted for XRF scanning and evaluated using Leica microscope located at Beamline 2-ID-E. After the initial scan to find baseline elements, the roots of the plants were put in an Arsenic solution for 1 hour. After the hour, the roots will be scanned to see any difference in the elemental makeup of the root systems. Using X-Ray fluorescence microscopy with optimum flux and spatial resolution, the elemental analysis of each plant will be compared to determine plant uptake of the elements.

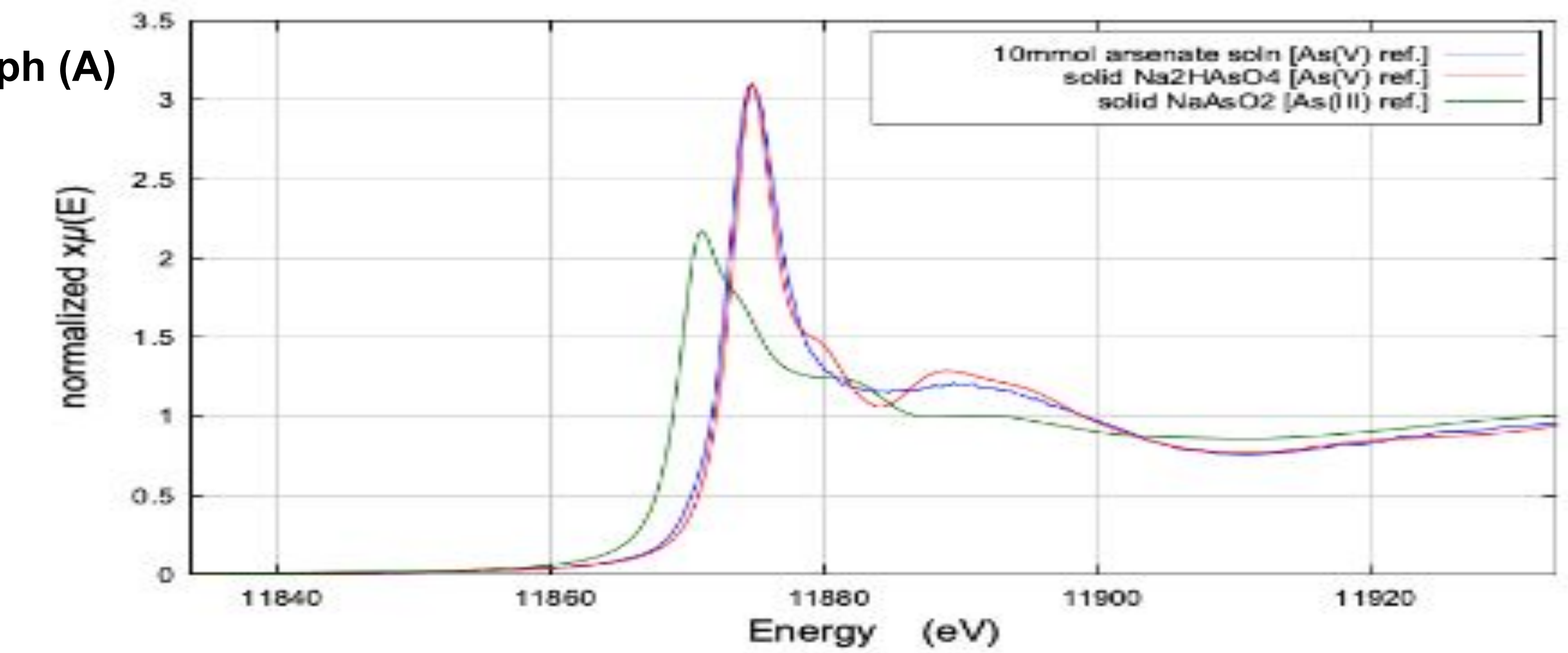
Root Pictures

The length rankings from smallest to largest: Oregano, Arabidopsis, Tomato, Carrot, and Lettuce

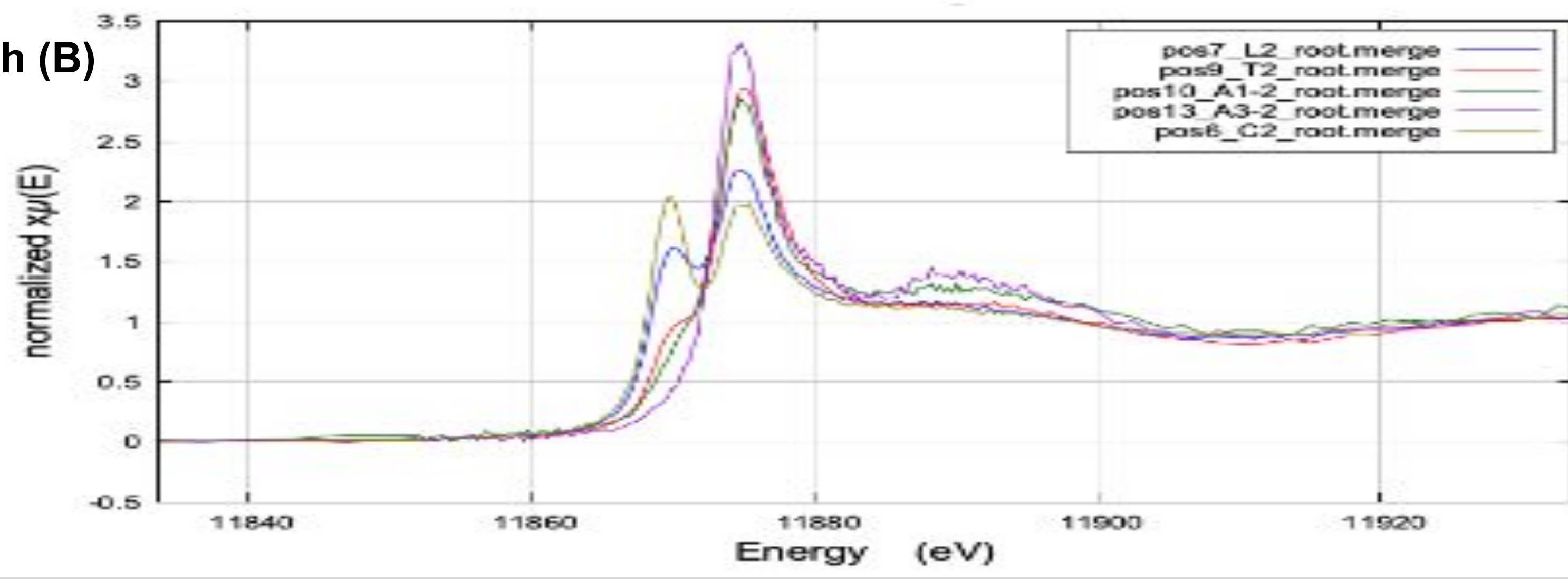
The root surface area rankings from smallest to largest: Carrot, Oregano, Arabidopsis, Lettuce, Tomato



Graph (A)



Graph (B)



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